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On the distribution of two species of *Copaifera* L. (Leguminosae) from the Brazilian Cerrado, and the first record of *C. malmei* Harms in São Paulo state, Brazil

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Abstract

Copaifera L. is a pantropical genus with great diversity in the Cerrado. Fieldwork in western São Paulo revealed the first record of *C. malmei* Harms in this state, and this is only the second time that this species has been found in the Southeast Region of Brazil. Additional analyses of a related species, *C. marginata* Benth. revealed the same rare pattern of distribution in the region. We provide morphological descriptions, comments on geographical distribution, assessment of conservation status, phenology, and an identification key to the species of *Copaifera* in the Cerrado in southeastern Brazil.

Keywords

Conservation, copaiba, Detarioideae

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Introduction

Copaifera L. (Detarioideae, Leguminosae) is a pantropical genus comprising 38 species, most of them widespread in the neotropics (Bentham 1870; Lewis et al. 2005; Costa 2007, 2009; LPWG 2017). *Copaifera* is morphologically distinguished from other genera of Leguminosae by the following combination of features: aromatic bark, paripinnate leaves, apetalous flowers, and fruits with a single seed covered by a conspicuous aril (Dwyer 1951, 1954; Costa 2007; Costa and Queiroz 2007). The species of *Copaifera* are generally known as copaíba, and several of them are recognized as medicinal and highly valued by the pharmaceutical and agrochemical industry for the antimicrobial and larvicidal activity of their aromatic oils (copaíba oil) and resins (Silva et al.

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2007; Veiga Junior et al. 2007; Santos et al. 2008). Currently, 26 species are recorded for the Brazilian flora, with greatest diversity in the Cerrado domain, where half of them occur (Costa 2020).

The Cerrado is the second largest phytogeographic domain in Brazil, and it is characterized by a rich vegetation mosaic ranging from grasslands and savannas to forest environments (Eiten 1972; Ribeiro and Walter 1998). The Cerrado, one of most species-rich domains for plants in the world, with 12,383 species (Ribeiro and Walter 1998; Klink and Machado 2005), is also considered as one of the most threatened, with about 366 plant species at risk of extinction (Martinelli et al. 2014). Large areas of the Brazilian Cerrado have been converted to pasture and monocultures of soy (Fernandes et al. 2016; Balbinot Junior 2017), eucalyptus, and pine plantations (Maquere et al. 2008; Araújo et al. 2010; Gonçalves et al. 2016). However, despite its great biodiversity and uniqueness, only a quarter of the domain is protected in conservation units (Strassburg et al. 2017).

Despite the high rates of environmental devastation, native vegetation remnants of relevant floristic diversity can still be found in São Paulo state (Rodrigues and Bononi 2008); the midwest part of this state is characterized by the transition between the Cerrado and the Atlantic Forest domains (SMA 2017). During an expedition in Cerrado areas of the state, we found a peculiar specimen of *Copaifera* that was preliminarily identified as *C. marginata* Benth.; a more detailed analysis later confirmed its identity as a closely related species, *C. malmei* Harms. Our research found that this is the first record of the species in the state, and also in the Southeast Region in Brazil. Besides sharing several morphological features, *C. malmei* and *C. marginata* are both typical species of the Cerrado where their distributions overlap. Both are very rare in southeastern Brazil. Thus, in addition to the new record of *C. malmei*, we also discuss the morphology and distribution of *C. marginata*. We provide descriptions, morphological, phenological, and conservation data, and an identification key to *Copaifera* species occurring in the Cerrado of the Southeast Region.

Methods

This study was based on field expeditions and analysis of specimens deposited in the main herbaria in Brazil and abroad, through visits or loan requests, complemented by consults to virtual collections (Species Link http://www.splink.org.br and Reflora Virtual Herbarium http://floradobrasil.jbrj.gov.br/reflora/herbarioVirtual). A voucher specimen of the new record is deposited in the herbarium of the Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo (ESA). The conservation status assessment was based on the International Union for the Conservation of Nature criteria (IUCN 2012) using area of occupancy (AOO) and extent of occurrence (EOO) obtained from GeoCAT (Geospatial Conservation Assessment Tool; Bachman et al. 2011). A map of geographical distribution was made with QGIS (2019) with shapefiles obtained from the Terrabrasilis platform (http://terrabrasilis.dpi.inpe.br/en/home-page/).

Results

Copaifera malmei Harms

New record. BRAZIL – **São Paulo** • Araraquara, Rodovia sentido Matão; 21°41′51″S, 048°13′30″W; 6.IX.2019; A. Maruyama leg.; ESA 143631.

Material examined. BRAZIL – **Bahia** • Santa Maria da Vitória, BR, entre Sta. Ma. da Vitória e Correntina, entrada à direita, no sentido Sta. Ma. da Vitória-Correntina, em frente ao cemitério; 13°23′02″S, 044°34′00″W; 22.VII.2003; J.A.S. Costa leg.; HUEFS 73949 – **Goiás** • Monte Alegre de Goiás, 24 km by road SW of Monte Alegre de Goiás; 13°27′00″S, 047°13′48″W; 11.III.1973; W.R. Anderson leg.; IAN 149170 – **Mato Grosso** • São José do Rio Claro, Fazenda Cachoeira de Pau; 13°52′S, 056°31′W; 14.VI.1997; V.C. Souza et al. leg.; HUEFS 70084 – **Mato Grosso do Sul** • Corumbá, Pazenda Ipameri; 11.VI.1994; G. Hatschbach leg; MBM 167440 – **Minas Gerais** • Buritizeiro, Rod. BR-365, Chapada dos Gerais, 69 km S do Rio São Francisco; 12.IV.1996; G. Hatschbach leg.; MBM 193110 – **Piauí** • Gilbués, Estrada Bom Jesus, a 140 km de Bom Jesus; 09°49′54″S, 045°20′38″W; 11.XI.1979; A. Fernandes leg.; EAC 7225 – **Tocantins** • Guaraí, 10 km S of Guará; 08°55′48″S, 048°31′12″W; 19.III.1968; H.S. Irwin leg; NY 2063081.

Identification. Shrub to subshrub 1–3 m tall. **Petioles** 1.0–2.5 cm long; rachis tomentose, 3–8 cm long; leaflets 3–5 pairs; petiolules 2.5–3.5 mm long; lamina lacking translucent dots or rarely opaque, papyraceous to coriaceous, rarely rigid-coriaceous glaucous, elliptical or lanceolate, 3–7 × 2–4 cm, all equally sized, margin flat, apex obtuse, acute or mucronate, base obtuse, adaxial side pubescent or puberulous, rarely glabrous, abaxial side scabrous-hirsute; trichomes bulbous-glandular. **Panicle** 10–20 cm long, equal to or slightly longer than the adjacent leaf, rarely twice its size, usually scabrous-tomentose. **Flowers** sessile, sepals 3–4 × 1.5–2.0 mm, tomentose, pubescent, rarely glabrescent; stamens 10, filaments 5–9 mm long, anthers 1.5–2.0 mm long; ovary oblong, 1.5–2 × 1–1.5 mm, hirsute; style 2–5 mm long. **Legume** 2.0–2.8 × 1.6–2.1 cm, reddish, drying brown. **Seed** oblongoid; aril white (Fig. 1A–E).

Distribution and habitat. *Copaifera malmei* occurs exclusively in the Brazilian Cerrado domain in the North (Tocantins state), Northeast (Piauí and Bahia) and Central-West (Goiás, Mato Grosso and Mato Grosso do Sul) regions in Brazil, in cerrado (*sensu lato*) and campo limpo (grasslands) physiognomies (Costa 2007; Costa 2020). The recently discovered specimen from São Paulo is the second record of this species in the Southeast Region of Brazil. The first record from this region is from Minas Gerais state (Figs. 2, 3). The new record from São Paulo was found in a small fragment of cerradão

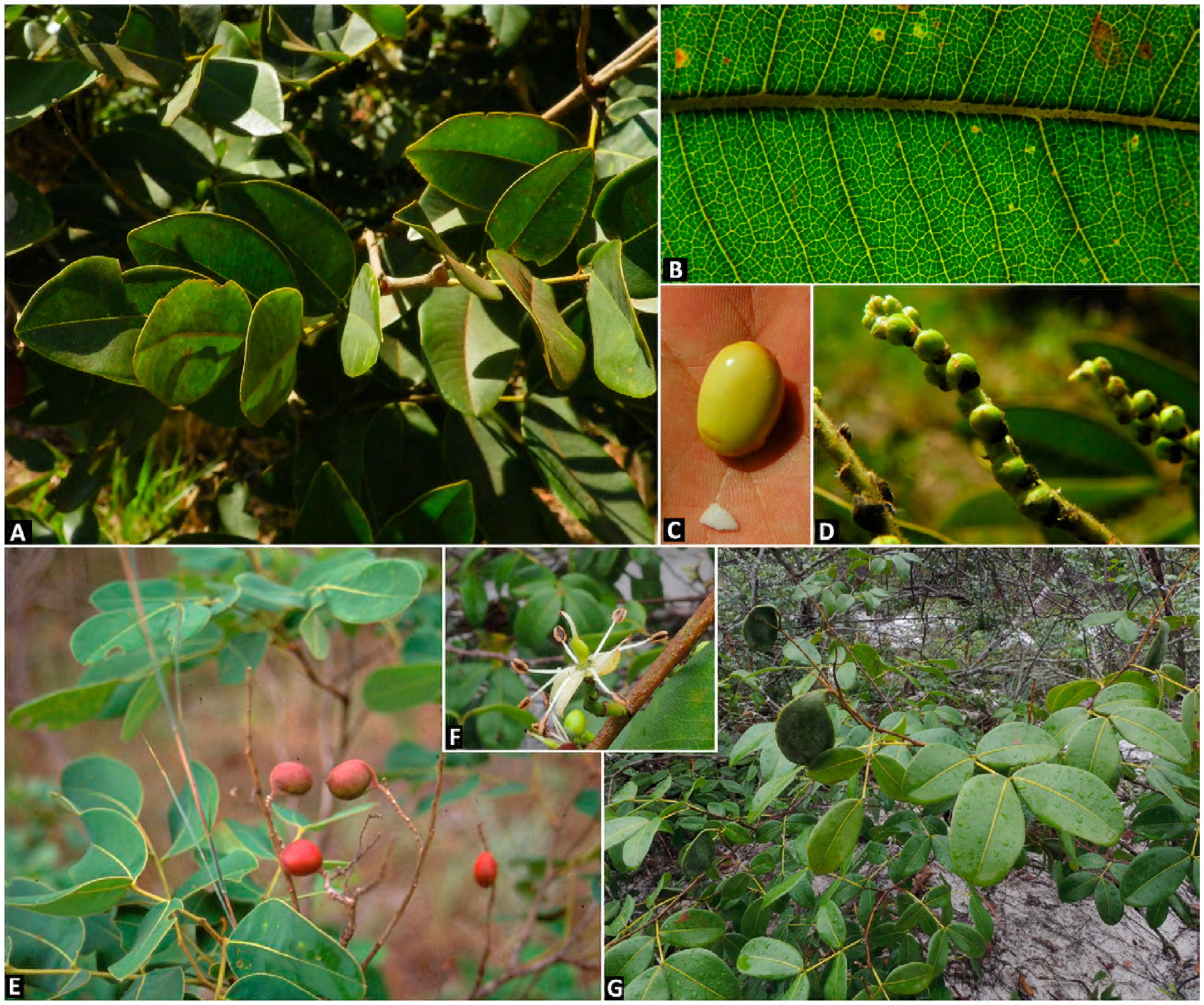

Figure 1. *Copaifera malmei* and *C. marginata*. **A–E.** *C. malmei* Harms: (**A**) vegetative branch; (**B**) venation of leaflet (adaxial side); (**C**) seed, with a fragment of the removed aril; (**D**) detail of inflorescence with buds; (**E**) branch with mature fruits. **F, G.** *C. marginata* Benth.: (**F**) detail of old flower; (**G**) branch with immature fruits. Photos: A–D by Adriano Maruyama; E by Jorge Antonio Silva Costa; F, G by Rubens Queiroz).

(dense, wooded savanna) along the roadside in an area that is prone to frequent clearing for road maintenance and fires. Our subsequent efforts to find this species at the site failed to find any individuals.

Phenology. *Copaifera malmei* was collected with flowers from February to May and with fruits from February to June and from October to November. The specimens from São Paulo state bore juvenile flowers and fruits when collected in October.

Copaifera marginata Benth.

Materials examined. BRAZIL – **Bahia** • Formosa do Rio Preto; 11°02′52″S, 045°11′34″W; 10.XI.1997; D. Alvarenga et al. leg; NY 470699 – **Goiás** • Niquelândia; estrada de acesso à Barra do Rio Bagagem com o Rio Tocantinzinho; 450 m s.a.l.; 20.VII.1995; T.B. Cavalcanti et al. leg; HUEFS 30019 – **Maranhão** • 8.VIII.1954; G.A. Black et al. leg.; IAN 83889 – **Mato Grosso** • Denise; estrada entre Bauxi e Alto Paraguai, ca. 35 km da MT 245, próximo ao povoado Capão Verde; 223 m a.s.l.; 20.IV.2005; J.A.S. Costa et al. Leg.; HUEFS 95415 – **Minas Gerais** •São Gonçalo do Abaeté; 20.III.1980; G. Hatschbach leg.; ESA 88848 – **Tocantins** • Mateiros, Rio Novo; 10°35′S, 046°39′W; 9.V.2001; L.H.S. Silva et al. leg.; CEN 41614.

Identification. Shrub 1.0–2.5 (–4) m tall. **Petioles** 1.0–1.3 cm long; rachis densely tomentose or rarely pubescent, 10–13 (–14) cm long; leaflets 2–4 pairs; petiolules 3–4 mm long; lamina lacking translucent dots, rarely opaque, rigid-coriaceous, rarely coriaceous, glaucous, elliptical-orbicular or elliptical, rarely elliptical-lanceolate, 7–10 (–12.3) × 4–6 (–6.4) cm, all equally sized, margin flat to subrevolute, apex obtuse to acute, emarginate-mucronate, base obtuse, adaxial side pubescent or puberulous, rarely glabrous, abaxial side sericeous or pubescent, rarely glabrous; trichomes simple. **Panicle** 15–38 cm long, twice or three times the length of the adjacent leaf, tomentose to densely pubescent, rarely pubescent. **Flowers** sessile, sepals 4–5 × 2.0–3.8 mm, tomentose, sericeous, rarely glabrous; stamens 10, filaments 5–7 (–9) mm long, anthers 1.5–2.0 mm long; ovary oblong, 2–3 × 1.4–2.5 mm, pubescent; style 1.9–4.8 mm long. **Legume** 2.5–3.0 × 1.6–2.1 cm, drying brown. **Seed** oblongoid; aril white (Fig. 1F, G).

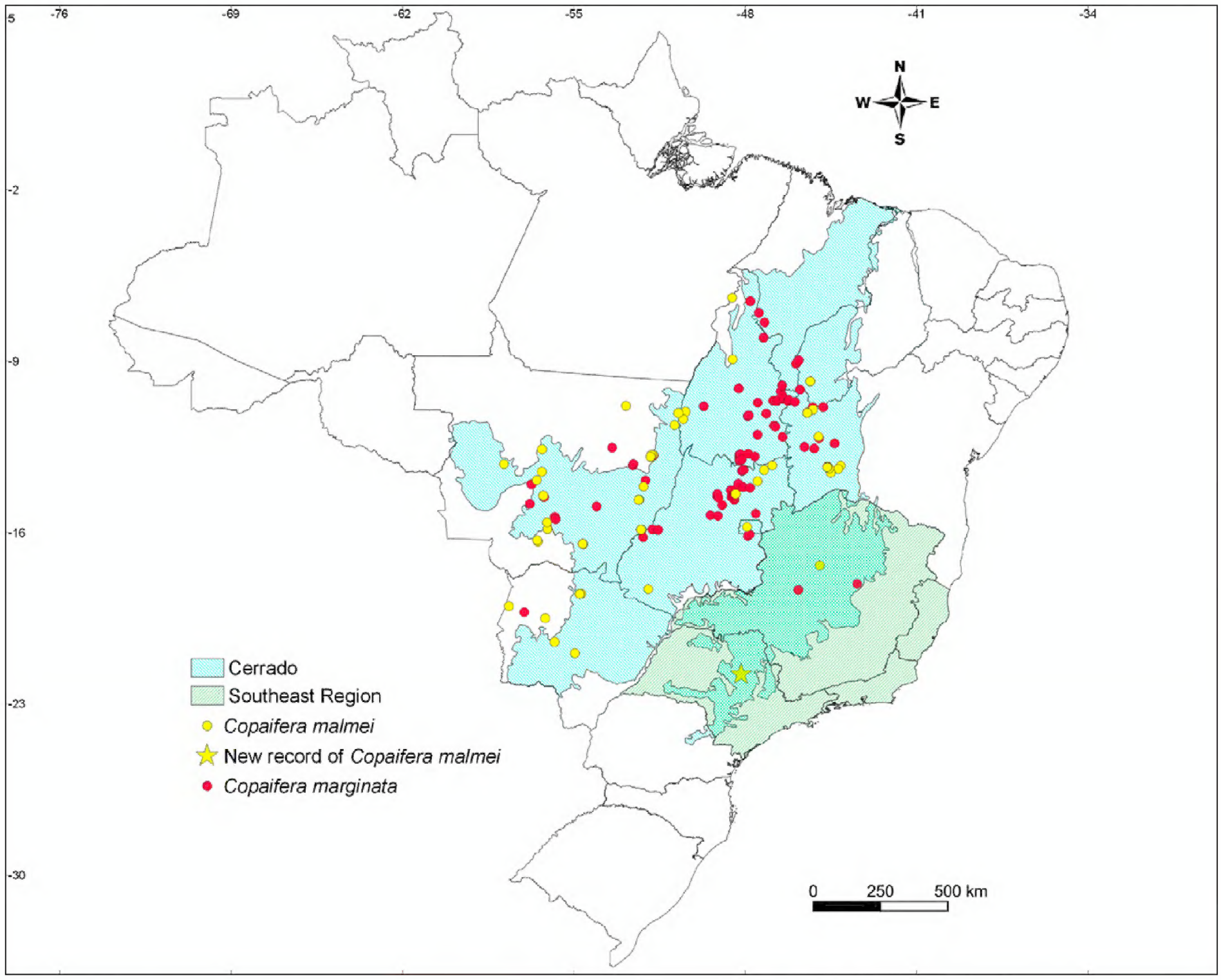

Figure 2. Detail of the distribution of *Copaifera malmei* Harms and *C. marginata* Benth. in the Cerrado of the Southeastern Region of Brazil.

Distribution and habitat. *Copaifera marginata* is restricted to the Brazilian territory in various physiognomies of the Cerrado domain, with records in the North (Tocantins state), Northeast (Bahia and Maranhão), and Central-West (Goiás, Mato Grosso do Sul and Mato Grosso) regions (Costa 2020). The species is a rare element of the Cerrado in the Southeast Region, where it is known from only two collections from Minas Gerais state (Figs. 2, 3).

Phenology. *Copaifera marginata* was collected with flowers from January to July and in November, and with fruits from April to July and from October to November.

Identification key to species of *Copaifera* occurring in the Cerrado of the Southeast Region of Brazil

1. Leaves with 2–3 (5) pairs of leaflets, the proximal leaflets about the same size as the distal and median.
   2. Leaflets with bulbous-glandular trichomes..... ..... *C. malmei*
   2′. Leaflets glabrate or with simple trichomes
      3. Leaves and inflorescence tomentose to densely pubescent, or glaucous, rarely pubescent..... ..... *C. marginata*
      3′. Leaves and inflorescence glabrate to puberulous ... *C. sabulicola* J.A.S.Costa & L.P.Queiroz

1′. Leaves with 3–5 (12) pairs of leaflets, the proximal leaflets smaller than the distal and median, usually half the size of these.
   4. Proximal leaflets twice smaller than the distal leaflets..... *C. langsdorffii* Desf. (with three varieties)
   4′. Proximal and distal leaflets equally sized or almost so..... *C. oblongifolia* Mart. (with two varieties)

Discussion

Copaifera malmei and *C. marginata* are morphologically very similar, which leads to frequent misidentifications in herbarium specimens. They can be distinguished from the remaining taxa of *Copaifera* by the shrubby habit and white aril covering the seeds, and although some of the diagnostic features between the two species often overlap, the presence of glandular trichomes on the leaves of *C. malmei* is unique within the genus. Other features that can be used to distinguish *C. malmei* from *C. marginata* are shown in Table 1.

Besides sharing several morphological features, both species are also exclusive to the Brazilian savanna, where their distributions overlap (Figs. 2, 3). Both species are actually quite common elements of the Brazilian

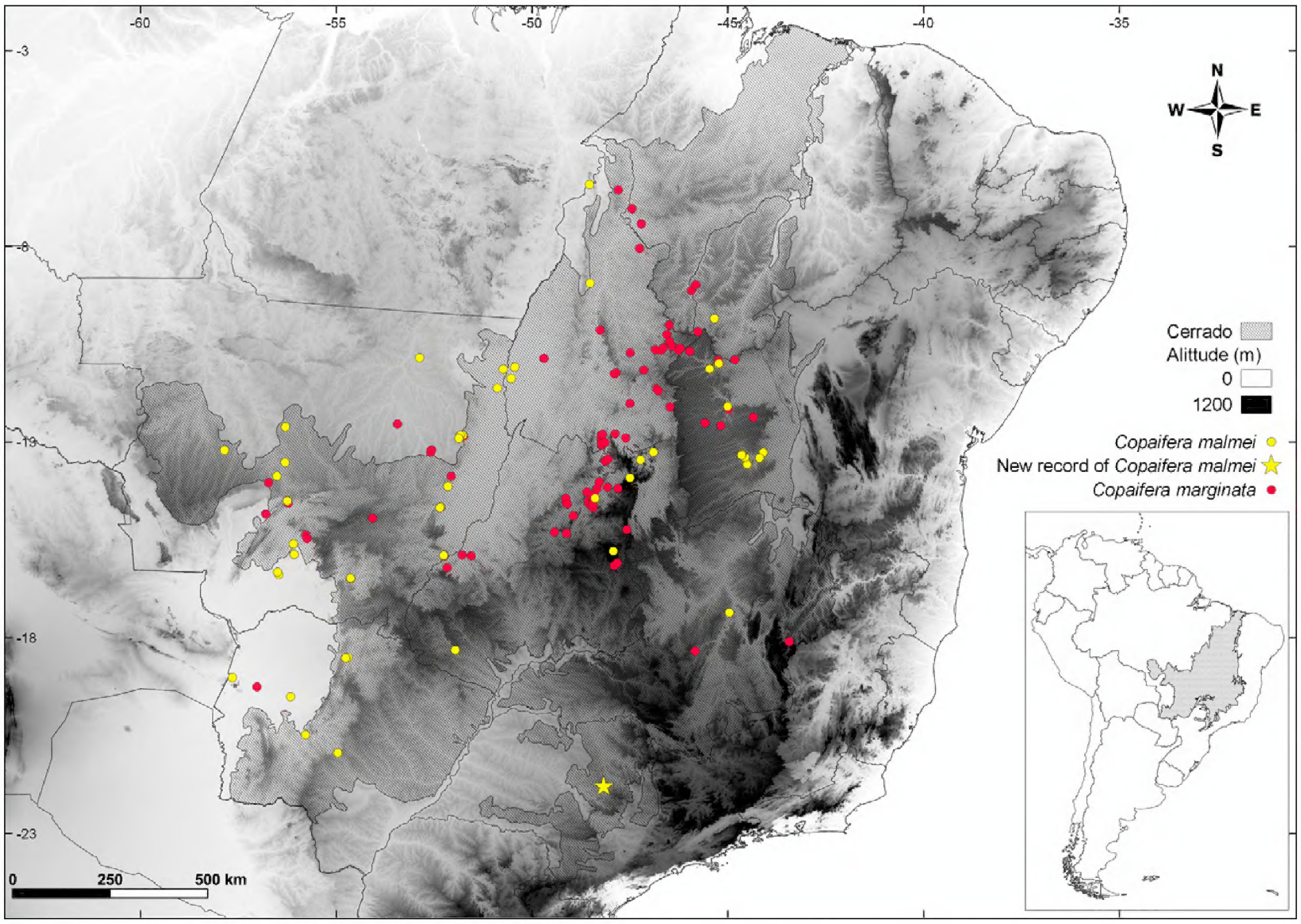

Figure 3. Geographical distribution of *Copaifera malmei* Harms and *C. marginata* Benth.

Cerrado, are rather widely distributed in this domain (EOO = 1,749,709 km², AOO = 208 km² for *C. malmei* and EOO = 1,353,085 km², AOO = 388 km² for *C. marginata*), and have abundant records from conservation units. Based on this and the IUCN criteria (IUCN 2012), we consider *C. malmei* and *C. marginata* both to be Least Concern. However, we emphasize the infrequency in which these species are found in the southeastern Brazilian savanna of São Paulo and Minas Gerais states (Fig. 2), and that none of the records from these states were collected in protected areas. We recommend that *C. malmei* is included in a future revision of the state's Red List (SMA 2016). Although the few specimens of *C. malmei* and *C. marginata* from Minas Gerais were collected long before the publication of the first two versions of this state's Red List (COPAM 1997; Biodiversitas 2008), they remained undetermined in herbarium collections until recently, which precluded their inclusion in the Red List.

The Cerrado holds the second largest protected area in Brazil following the Amazon, but between 2002 and 2011, deforestation in the Brazilian savanna was 2.5 times higher than in the rain forest of northern Brazil (Strassburg et al. 2017; Vieira et al. 2019). Furthermore, the area protected in the Cerrado is merely 8.6% of the domain (Vieira et al. 2019), meaning that most of its extent is exposed to land clearing for cattle raising and highly mechanized monocultures.

In São Paulo state, Cerrado formations cover 239,312 ha (1% of the native vegetation) and are very fragmented and concentrated in the central part of the state (Panzutti 2003; Instituto Florestal 2020; Figs. 2, 3). The Cerrado has been profoundly altered by urban and agricultural activities in São Paulo, and the characteristic fragmentary distribution of the domain in the state greatly hinders rational and sustainable economic initiatives for the exploration of its resources, as seen in wider areas of Cerrado in Minas Gerais and the Central-West Region. The disturbances to the native vegetation in the area where *C. malmei* was found in São Paulo are caused mainly by the conversion to pastures and sugar cane, citrus, and

Table 1. Diagnostic features between *Copaifera malmei* and *C. marginata*.

Features	*Copaifera malmei*	*Copaifera marginata*
Indument of leaflets	Adaxial side pubescent or puberulous, rarely glabrous, abaxial side scabrous-hirsute	Adaxial side pubescent or puberulous, rarely glabrous, abaxial side sericeous or pubescent, rarely glabrous
Texture of leaflets	Papyraceous to coriaceous, rarely rigid-coriaceous	Rigid-coriaceous, rarely coriaceous
Type of trichome	Bulbous-glandular	Simple
Size of inflorescence	Equal or slightly longer than the adjacent leaf, rarely twice its size	Twice or three times the length of the adjacent leaf

temporary crops, and reforestation with exotic species (Panzutti 2003). As mentioned above, our subsequent visit to the site in Araraquara where we had found *C. malmei* a couple of years earlier failed to find any individuals of the species. This calls attention to the urgent need to prevent total extirpation of this rare species in the area of the highway caused by routine maintenance.

The state of Minas Gerais has 54% of its territory covered by Cerrado, of which only 22.3% hold native vegetation (IEF-MG 2020). The areas where *Copaifera malmei* and *C. marginata* were collected, mostly in the western part of the state, have their history linked to the Brazilian Gold Rush, in which the wealth that circulated within the region did not prevent it from growing into the impoverished land observed today, probably as a result of the misuse of its natural resources and vegetation cover (Carrara 2007). This misuse was further aggravated by a matrix of land use linked to cattle raising and large-scale irrigated agriculture in subsequent economic cycles, activities that have long been practiced mainly in large country estates and are in great part responsible for land occupation and the formation of cities, with serious damage to native vegetation (Leite et al. 2014). However, it is unclear whether the lack of records of *C. malmei* and *C. marginata* in the western part of the state where these species were collected is due to the long history of deforestation, collection gaps, or their natural local pattern of distribution. The single record of *C. marginata* from Diamantina in the Espinhaço Range might be a good evidence of the naturally low frequency of this species in the state, as this region has been focus of intense collection efforts during the last decades; Diamantina is a relatively well collected site. A recent threat to the vegetation of the Espinhaço Range is the monoculture of large areas of eucalyptus and pine (Rapini et al. 2008); thus, the discovery of a rare species such as *C. marginata* in Diamantina is at the same time evidence of the necessity of fieldwork even in areas that are thought to be sufficiently sampled.

The rare occurrences of *C. malmei* and *C. marginata* in the savanna of southeastern Brazil are important because of the threats to their natural habitats. Brazil is a signatory to many international agreements, including the 2030 Agenda for Sustainable Development (Convention on Biological Diversity 2020), which includes commitments to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss and to take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and protect and prevent the extinction of threatened species. Sustainable development, however, must also consider socioeconomic aspects, and the Brazilian Cerrado, as a biodiversity hotspot, holds most favorable conditions for the sustainable exploration of their natural resources by local populations. Food and nutraceutical resources, cosmetics, and pharmaceutical compounds are among the products of Brazilian plant species, including those extracted from *Copaifera* species (Pieri et al. 2009; Christel 2017). Many are patented by national and foreign companies, but local communities have received little, if any, financial return from the exploitation of their land's biodiversity (Prates et al. 2020). Therefore, the economic involvement of locals in sustainable exploration of the Brazilian savanna allied to the study of rare and endemic species and their conservation is paramount in building public policies towards the reconciliation of socioeconomic development, agricultural expansion, conservation of the remaining areas, and restoration of critical habitats for endangered species.

The first record of *Copaifera malmei* in São Paulo shows that even small fragments of Cerrado in very anthropized regions such as the municipality of Araraquara are important for maintaining biodiversity and must be preserved and connected to other fragments in ecological restoration programs. Better understanding of the distributions of *C. malmei* and *C. marginata* will contribute to a better assessment of their conservation status and local distribution patterns in São Paulo and Minas Gerais states, and will allow for the construction of public policies towards the conservation and restoration of their Cerrado remnants.

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Authors' Contributions

AM collected the new record, made the preliminary identification of the specimen, and photographed the species (Fig. 1A–D); AG wrote the manuscript; JPS wrote the manuscript and prepared the maps; JASC confirmed the identification and photographed the species (Fig. 1E).

References

Araújo ASF, Silva EFL, Nunes LAPL, Carneiro RFV (2010) The effect of converting tropical native savanna to *Eucalyptus grandis* forest on soil microbial biomass. Land Degradation & Development 21 (6): 540–545. https://doi.org/10.1002/ldr.993

Bachman S, Moat J, Hill AW, Torre J, Scott B (2011) Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. ZooKeys 150: 117–126. https://doi.org/10.3897/zookeys.150.2109

Balbinot Junior AA, Franchini JC, Debiasi H, Yokoama AH (2017) Contribution of roots and shoots of *Urochloa* species to soybean

performance in succession. Pesquisa Agropecuária Brasileira 58: 592–598. https://doi.org/10.1590/s0100-204x2017000800004

Bentham G (1870) Leguminosae II et III. Swartzieae, Caesalpinieae, Mimoseae. In: Martius KFP, Eichler AG (Eds.) Flora brasiliensis. Frid. Fleischer in Comm., Munich/Leipzig, 528 pp.

Biodiversitas (2008) Listas Vermelhos das espécies da fauna e da flora ameaçada de extinção em Minas Gerais. http://www.biodiversitas.org.br/cdlistavermelha/default.asp. Accessed on: 2020-8-16.

Carrara AA (2007) Antes das Minas Gerais: conquista e ocupação dos sertões mineiros. Universidade Federal de Minas Gerais Belo Horizonte, Brasil. Varia História, 23: 574–596. https://doi.org/10.1590/S0104-87752007000200019

Christel FP (2017) Utilisation de *Copaifera* en cosmetique et en dermatologie. French Patent Application FR1752281, Laboratorios Pierre Fabre Do Brasil Ltda, Pierre Fabre Dermo Cosmetique SA. https://patentimages.storage.googleapis.com/16/59/78/224f2589e3624b/FR3063905A1.pdf. Accessed on: 2020-9-14.

Convention on Biological Diversity (2020) Biodiversity and the 2030 Agenda for sustainable development – technical note. Secretariat of the Convention on Biological Diversity, Montreal, Canada. https://www.cbd.int/development/doc/biodiversity-2030-agenda-technical-note-en.pdf. Accessed on: 2020-9-14.

COPAM (Conselho Estadual de Política Ambiental) (1997) Deliberação COPAM nº 85, de 21 de outubro de 1997 — aprova a lista das espécies ameaçadas de extinção da flora do estado de Minas Gerais. http://www.siam.mg.gov.br/sla/download.pdf?idNorma=5483. Accessed on: 2020-8-12.

Costa JAS (2007) Estudos taxonômicos, biossistemáticos e filogenéticos em *Copaifera* L. (Leguminosae – Detarieae) com ênfase nas espécies do Brasil extra-amazônico. PhD thesis, Universidade Estadual de Feira de Santana, Feira de Santana, Brazil, 233 pp.

Costa JAS (2009) A new combination in the genus *Copaifera* (Leguminosae). Neodiversity 4: 14–15.

Costa JAS (2020) *Copaifera* in flora do Brasil 2020. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/reflora/floradobrasil/FB22895. Accessed on: 2020-8-16.

Costa JAS, Queiroz LP (2007) *Copaifera sabulicola* (Leguminosae), uma nova espécie do cerrado brasileiro. Rodriguésia 58 (2): 393–396. http://doi.org/10.1590/2175-7860200758213

Dwyer JD (1951) The Central American, West Indian, and South American species of *Copaifera* (Caesalpinioideae). Brittonia 7(3): 143–172. https://doi.org/10.2307/2804703

Dwyer JD (1954) Further studies on the New World species of *Copaifera*. Bulletin of the Torrey Botanical Club 81 (3): 179–187. https://doi.org/10.2307/2481808

Eiten G (1972) The Cerrado vegetation of Brazil. The Botanical Review 38 (2): 201–341. https://doi.org/10.1007/BF02859158

Fernandes GW, Pedroni F, Sanchez M, Scariot A, Aguiar LMS, Ferreira G, Machado R, Ferreira ME, Diniz S, Pinheiro R, Costa JAS, Dirzo R, Muniz F (2016) Cerrado: em busca de soluções sustentáveis. Vertente Produções Artísticas, Rio de Janeiro, Brazil, 212 pp.

Gonçalves TAP, Nisgoski S, Oliveira JS, Marcati CR, Ballarin AW, Muñiz, GIB (2016) A contribution to the identification of charcoal origin in Brazil II—macroscopic characterization of Cerrado species. Anais da Academia Brasileira de Ciências 88 (2): 1045–1054. https://doi.org/10.1590/0001-3765201620150322

IEF-MG (Institudo Estadual de Florestas de Minas Gerais) (2020) Cobertura vegetal de Minas Gerais. http://www.ief.mg.gov.br/florestas. Accessed on: 2020-8-12.

Instituto Florestal (2020) Inventário florestal do estado de São Paulo—mapeamento da cobertura vegetal nativa. Secretaria de Infraestrutura e Meio Ambiente, São Paulo. https://smastr16.blob.core.windows.net/home/2020/07/inventarioflorestal2020.pdf. Accessed on: 2020-6-23.

IUCN (International Union for the Conservation of Nature) (2012) IUCN Red List categories and criteria, version 3.1. Second edition. Gland, Switzerland / Cambridge, UK, 32 pp. https://portals.iucn.org/library/sites/library/files/documents/RL-2001-001-2nd.pdf. Accessed on: 2020-5-20.

Klink CA, Machado RB (2005) Conservation of the Brazilian Cerrado. Conservation Biology 19 (3): 707–13. https://doi:10.1111/j.1523-1739.2005.00702.x

Leite ME, Clemente CMS, Pereira DM, Martins AS (2014) Mapeamento da dinâmica espaço-temporal dos pivôs centrais no norte de Minas gerais, através do sensoriamento remoto. Campo-Território: Revista de Geografia Agrária 9 (17): 418–435.

Lewis GP, Schrire B, Mackinder B, Lock M (2005) Legumes of the world. Royal Botanic Gardens, Kew, UK, 369 pp.

LPWG (2017) A new subfamily classification of the Leguminosae based on a taxonomically comprehensive phylogeny: The Legume Phylogeny Working Group (LPWG). Taxon 66 (1): 44–77. https://doi.org/10.12705/661.3

Maquere V, Laclau JP, Bernoux M, Saint-Andre L, Gonçalves JLM, Cerri CC, Piccolo MC, Ranger J (2008) Influence of land use (savanna, pasture, *Eucalyptus* plantations) on soil carbon and nitrogen stocks in Brazil. European Journal of Soil Science 59(5): 863–877. https://doi.org/10.1111/j.1365-2389.2008.01059.x

Martinelli G, Moraes L, Moulton L, Santos Filho L, Negrão R, Avancini R, Amaro R, Messina T (2014) Avaliações de risco de extinção das plantas raras do Cerrado: resultados, desafios e perspectivas. In: Martinelli G, Messina T, Santos Filho L (Eds.) Livro Vermelho da flora do Brasil—plantas raras do Cerrado. Andrea Jakobsson, Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, CNCFlora, Rio de Janeiro, Brazil, 25–41.

Panzutti NPM (2003) Utilização e conservação dos fragmentos do Cerrado no estado de São Paulo. Secretaria de Agricultura e Abastecimento, Instituto de Economia Agrícola (IEA). http://www.iea.sp.gov.br/out/LerTexto.php?codTexto=642. Accessed on: 2020-6-23.

Pieri FA, Mussi MC, Moreira MAS (2009) Copaiba oil (*Copaifera* sp.): history, extraction, industrial applications and medicinal properties. Revista Brasileira de Plantas Medicinais 11 (4): 165–472. https://doi.org/10.1590/S1516-05722009000400016

Prates SMS, Mügge FLB, Paula-Souza J, Brandão MGL (2020) Potencial econômico das plantas usuais dos brasileiros: espécies da Bacia do Rio Pandeiros. Revista a Flora 1: 8–13.

Rapini A, Ribeiro PL, Lambert S, Pirani JR (2008) A flora dos campos rupestres da Cadeia do Espinhaço. Megadiversidade 4 (1–2): 15–23.

Ribeiro JF, Walter BMT (1998) Fitofisionomia do Bioma Cerrado. In: Sano SM, Almeida SP (Eds.) Cerrado: ambiente e flora. Embrapa, Brasília, Brazil, 89–166.

Rodrigues RR, Bononi VLR (2008) Diretrizes para conservação e restauração da biodiversidade no estado de São Paulo. Instituto de Botânica, São Paulo, Brazil, 248 pp.

Santos AO, Ueda-Nakamura T, Dias Filho BP, Veiga Junior VF, Pinto AC, Nakamura CV (2008) Antimicrobial activity of Brazilian copaiba oils obtained from different species of the *Copaifera* genus. Memórias do Instituto Oswaldo Cruz 103 (3): 277–281. http://doi.org/10.1590/S0074-02762008005000015

Silva HHG, Geris R, Rodrigues Filho E, Rocha C, Silva IG (2007) Larvicidal activity of oil-resin fractions from the Brazilian medicinal plant *Copaifera reticulata* Ducke (Leguminosae–Caesalpinoideae) against *Aedes aegypti* (Diptera, Culicidae). Revista da Sociedade Brasileira de Medicina Tropical 40 (3): 264–267. https://doi.org/10.1590/S0037-86822007000300002

SMA (Secretaria do Meio Ambiente) (2016) Resolução SMA Nº 57, de 05 de Junho de 2016. Publica a segunda revisão da lista oficial das espécies da flora ameaçadas de extinção no estado de São Paulo. https://www.infraestruturameioambiente.sp.gov.br/institutodebotanica/wp-content/uploads/sites/235/2016/06/Resolucao-SMA-057-05_2016.pdf. Accessed on: 2020-8-12.

SMA (Secretaria do Meio Ambiente) (2017) Resolução SMA Nº 146, de 08 de Novembro de 2017. Institui o Mapa de Biomas do estado de São Paulo, e dá outras providências. http://arquivos.ambiente.

sp.gov.br/legislacao/2017/11/resolucao-sma-146-2017.pdf. Accessed on: 2020-06-13.

Strassburg B, Brooks T, Feltran-Barbieri R, Iribarrem A, Crouzeilles R, Loyola R, Latawiec AE, Oliveira Filho FJB, Scaramuzza CAM, Scarano FR, Soares-Filho B, Balmford A (2017) Moment of truth for the Cerrado hotspot. Nature Ecology and Evolution 1: 0099. https://doi.org/10.1038/s41559-017-0099

Veiga Junior VF, Rosas EC, Carvalho MV, Henriques MGMO, Pinto AC (2007) Chemical composition and anti-inflammatory activity of copaiba oils from *Copaifera cearensis* Huber ex Ducke, *Copaifera reticulata* Ducke and *Copaifera multijuga* Hayne—a comparative study. Journal of Ethnopharmacology 112 (2): 248–254. https://doi.org/10.1016/j.jep.2007.03.005

Vieira RRS, Pressey RL, Loyola R (2019) The residual nature of protected areas in Brazil. Biological Conservation 233: 152–161. https://doi.org/10.1016/j.biocon.2019.02.010